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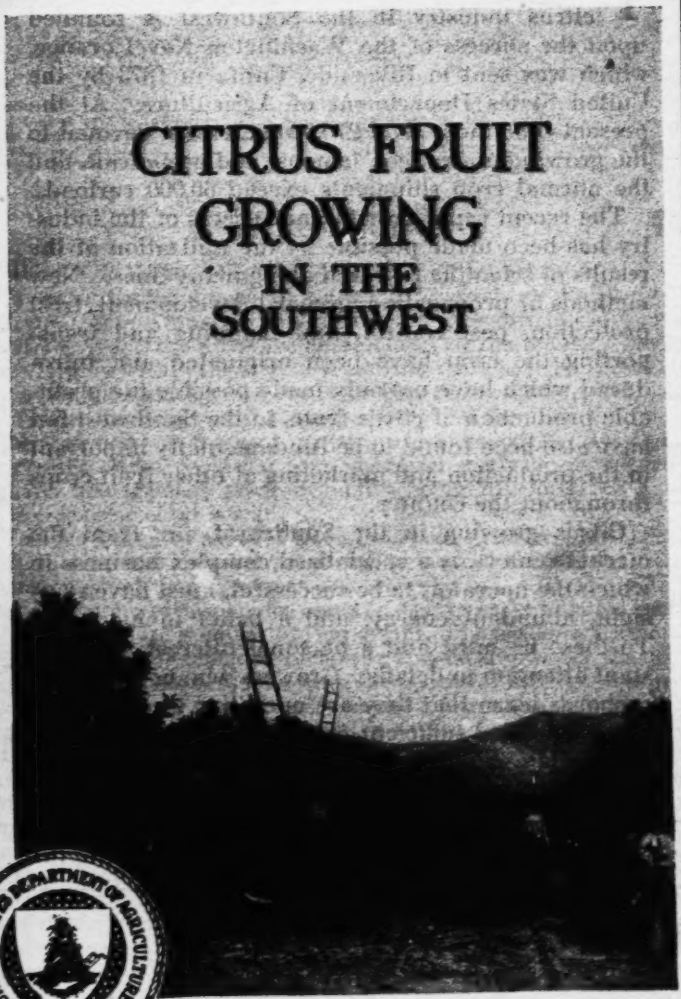
FARMERS' BULLETIN No. 1447

CITRUS FRUIT GROWING IN THE SOUTHWEST



THE COMMERCIAL DEVELOPMENT of the citrus industry in the Southwest is founded upon the success of the Washington Navel orange, which was sent to Riverside, Calif., in 1873 by the United States Department of Agriculture. At the present time more than 270,000 acres are devoted to the growing of oranges, lemons, and grapefruit, and the normal crop shipments exceed 60,000 carloads.

The recent rapid growth and success of the industry has been made possible by the utilization of the results of scientific research along many lines. New methods of propagation, orchard development, frost protection, pest control, and handling and transporting the crop have been originated and introduced which have not only made possible the profitable production of citrus fruits in the Southwest but have also been found to be fundamentally important in the production and marketing of other fruit crops throughout the country.

Citrus growing in the Southwest, far from the market centers, is a specialized complex business in which the operator, to be successful, must have foresight, abundant energy, and a belief in his work. To these he must add a personal interest and constant attention to details. Growers who neglect their orchards learn that they are operating at a loss, but those who give sufficient food, water, and work find their balances on the right side of the ledger.

Washington, D. C. Issued July, 1925

CITRUS FRUIT GROWING IN THE SOUTHWEST

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INTRODUCTION

THE COMMERCIAL GROWTH of citrus fruits in the southwestern United States is limited to districts in California and Arizona. While oranges doubtless have been grown in California for about 150 years, the extensive development of the industry has taken place largely within the last 30 years, and there is still a great diversity of opinion among growers regarding the most successful methods of conducting some of the fundamental practices of the business. Public agencies and many growers are engaged in investigations of various citrus problems, and improved methods of culture and orchard management are continually being developed as a result of this experimental work.

Various phases of some of these improved practices have been discussed in the horticultural press and announced through bulletins or at meetings of fruit growers, but there is no general treatise on citrus culture which includes many of the recently adopted methods of conducting a number of important orchard operations. The present bulletin is intended to supply this lack, in order that the established citrus growers may have the benefit of such knowledge and that the newcomer may have reliable information as to the most dependable methods to be followed in caring for an orchard.

Citrus growing in Arizona has only recently become of commercial importance, and many cultural practices have not been thoroughly tested there as yet; hence the methods described in the following pages must of necessity deal largely with California conditions and the developments which have followed the growth of the industry in that State. However, the fundamental principles underlying successful citrus culture in California apply generally to the conditions in the Southwest as a whole.

DEVELOPMENT OF THE INDUSTRY

It is impossible to determine the date when oranges were first planted in California or Arizona, but it is certain that scattering trees were grown at some of the first Franciscan missions which

were founded in California in the latter part of the eighteenth century. Orchards and vineyards were established at all these missions, being propagated from plantings at the older missions in Lower California. Trees and vines from these early plantings were set in many private gardens, and the Mission olive, Mission grape, Mission fig, and orange seedlings from the mission grounds formed the basis for the first commercial developments in fruit growing in the Southwest.

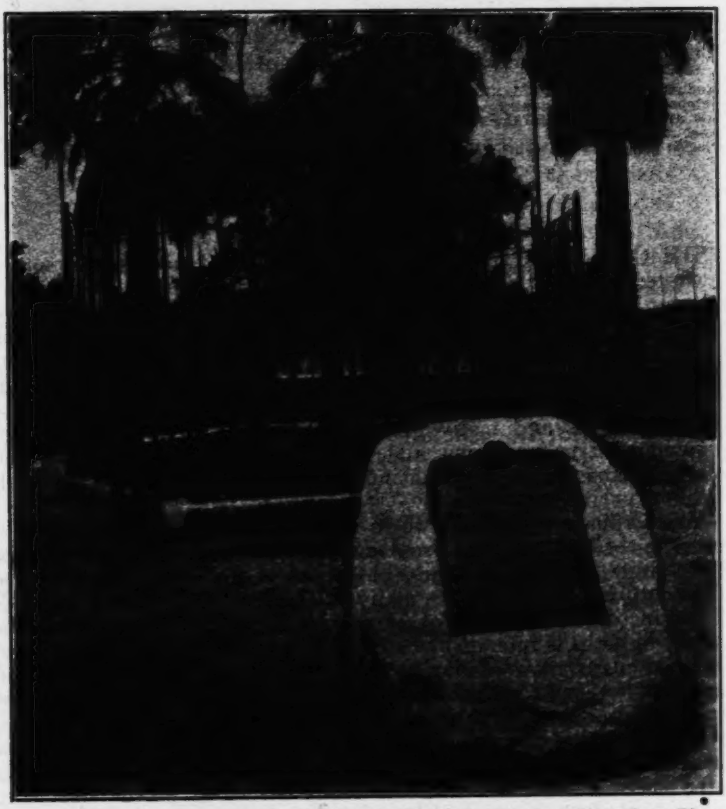

FIG. 1.—One of the two parent Washington Navel orange trees planted at Riverside, Calif., in 1873, from which most of the trees in the California and Arizona Washington Navel orchards have descended. (Photographed in May, 1922)

DEVELOPMENT IN CALIFORNIA

The nucleus of the present California citrus industry doubtless was formed at the San Gabriel Mission, near Los Angeles, in 1804 or 1805, when about 400 seedling trees were planted in an orchard of 6 acres for the use of persons connected with the mission. The first commercial orange orchard is believed to have been started by William Wolfskill at Los Angeles in 1841. By 1870 small scattered

plantings in many parts of the State had demonstrated that much of the foothill territory from San Diego to Butte County was suitable for citrus culture.

The beginning of the commercial development of the California citrus industry is considered as dating from the completion of the Southern Pacific Railroad from Oakland to Los Angeles in 1876, which opened the way for direct shipments out of the State. The opening of the Southern Pacific line to New Orleans in 1881 and the completion of the Santa Fe Railroad in 1885 gave added stimulus for further commercial plantings. Another important factor in the upbuilding of the industry was the fruiting of the Washington Navel orange at Riverside about 1878, when this variety was found to be much superior to any then grown. One of the two trees of this variety which were sent to Riverside from the United States Department of Agriculture in 1873 is shown in Figure 1.

The region in which citrus fruits are now commercially grown in California is an extensive one, reaching from the northern part of Glenn County to the southern part of San Diego County, a distance of about 550 miles from north to south and varying in width from 3 to 75 miles. This general region is subdivided geographically into three sections: (1) Southern California, including the coast regions from San Diego to Santa Barbara, the valleys of the Santa Ana and San Gabriel Rivers, and plantings in the Coachella and Imperial Valleys, these districts representing San Diego, Orange, Los Angeles, Ventura, San Bernardino, Riverside, Santa Barbara, and Imperial Counties; (2) central California, comprising the plantings along the foothills of the Sierras, mainly in Kern, Tulare, and Fresno Counties; and (3) northern California, where less extensive plantings are found in Glenn, Butte, Colusa, Placer, Sacramento, Solano, and several other counties.

TABLE 1.—*Plantings of oranges, lemons, and grapefruit in California, by principal counties, January 1, 1924*[1]

County	Orchard areas (acres)[2]					
	Oranges		Lemons		Grapefruit	
	Bearing	Nonbearing	Bearing	Nonbearing	Bearing	Nonbearing
Butte	1,850	53	46		16	
Sacramento	1,530	25			40	
Other northern	1,375	69	800		20	
Fresno	2,088	424	200	140	5	12
Kern	1,225	75	10		38	
Tulare	35,686	87	2,678	4	1,172	3
Other central	232	24	26	13		
Imperial					450	1,500
Los Angeles	39,825	6,613	11,263	4,277	378	97
Orange	41,226	3,151	9,536	1,485	63	28
Riverside	18,753	588	5,005	186	453	147
San Bernardino	38,759	1,933	5,000	600	1,500	51
San Diego	4,342	45	7,092	341	84	16
Santa Barbara	130	16	1,360	14	8	
Ventura	3,132	1,344	5,611	317	10	
Total	190,153	14,447	48,627	7,377	4,237	1,854

[1] Data furnished by E. E. Kaufman, statistician, California Cooperative Crop-Reporting Service.

[2] Estimated plantings for 1923 not included are as follows: Oranges, 555 acres; lemons, 335 acres; grapefruit, 1,118 acres.

The citrus plantings as of January 1, 1924, are given by the California Cooperative Crop-Reporting Service as 268,703 acres, with about 24,000,000 trees. The distribution of the orange, lemon, and grapefruit acreage as of January 1, 1924, by counties having over

FIG. 2.—Map showing by black patches and dots the distribution of the citrus producing areas in California on January 1, 1924

1,000 acres is presented in Table 1, and the general distribution in the State is shown geographically in Figure 2. The citrus shipments from California during recent years are shown in Table 2.

The northern and central California districts are located in the interior valleys of the Sacramento and San Joaquin Rivers, respectively, where climatic conditions are rather extreme. The air is

nearly always hot and dry in summer, the days are usually clear and sunny, and the absence of dews and fogs is very marked. The winter rains are generally abundant, especially in the more northern sections.

TABLE 2.—*Citrus fruits shipped from California during the four crop years ended October 31, 1924*

[Data furnished by the California Citrus League. The shipments in 1921-22 were reduced by frost damage that winter]

Season ended October 31—	Shipments (carloads)	
	Oranges and grapefruit	Lemons
1920-21	48,350	11,797
1921-22	29,573	9,928
1922-23	50,966	8,741
1923-24	47,635	13,097

In the southern California district there are three areas climatically—the Coachella and Imperial Valleys, marked by even greater extremes of summer heat and dryness than the northern and central districts and with an average annual rainfall of only about 2 inches; the upper Santa Ana River Valley, which is somewhat like the northern and central districts in its dry summers and bright days but with much cooler nights; and the coast section, where the proximity of the Pacific Ocean makes the climate more equable, with cooler summers and warmer winters and where frequent heavy dews and fogs increase the atmospheric humidity.

The climatic extremes which mark the northern and central districts and the Coachella and Imperial Valleys are responsible for the more rapid maturing of the fruit in those sections, which permits marketing it somewhat earlier than in other parts of the southern district. We thus have the anomalous condition of oranges grown in Butte and Glenn Counties which are marketable earlier than those in San Diego County, more than 500 miles farther south.

DEVELOPMENT IN ARIZONA

The citrus industry in Arizona is about 35 years old and is still relatively small in extent. The old trees in the Ingleside grove in the Salt River Valley northeast of Phoenix are the survivors of what was probably the first citrus orchard in Arizona. Here in 1889, W. J. Murphy planted 20 acres of orange and lemon trees from California, together with a number of olive and other fruit trees. Their success resulted in additional plantings in that district, and to-day the commercial citrus development of the State is limited to an area within a radius of a few miles from this first grove, with the addition of a small acreage at Yuma.

The first orchard planting in the Yuma district was made on the mesa just south of Yuma in 1892 by H. W. Blaisdell, 20 acres being planted with oranges and lemons. The success of the venture was such that in 1900 40 acres more were planted to Washington Navel oranges and Marsh grapefruit. In later years the increasing demands of the city of Yuma for water resulted in the neglect of the

orchard, and the lack of available water was the limiting factor for several years in preventing new plantings. In 1916 about 100 acres of Washington Navel oranges and Marsh grapefruit were planted by homesteaders and irrigated by pumping from the valley canal of the United States Reclamation Service. An auxiliary project on the mesa was opened by the Reclamation Service in 1919, but the lack of nursery trees and the strict quarantine against their importation prevented practically all plantings until 1923, after the quarantine had been modified with respect to trees for planting at Yuma.

On July 1, 1924, there were about 1,600 acres of citrus fruits in the Salt River Valley, approximately half being oranges (700 acres of Washington Navel) and the other half grapefruit (about 700 acres of the Marsh variety). All but about 200 acres of this was of bearing age, 75 acres having been planted in 1924, of which 60 acres were Marsh grapefruit.

The citrus production in the Salt River Valley during the 1923–24 season was approximately 200 cars of grapefruit, 130 cars of oranges (80 of the Washington Navel variety), and 5 cars of lemons. Practically 85 per cent of this fruit was handled by a cooperative association.

At Yuma there were on July 1, 1924, about 575 acres of citrus orchards, only 130 acres of which were of bearing age. About one-fourth of the plantings were Washington Navel oranges, and the remainder Marsh grapefruit, with a few lemon trees and other orange varieties. More than 435 acres were planted in 1923 and 1924. This district in the season of 1923–24 produced more than 10,000 field boxes of fruit, which were sold locally and in Los Angeles.

KINDS OF CITRUS FRUITS IN THE SOUTHWEST

The citrus industry of the Southwest was founded upon and has been developed very largely with the common round sweet orange, and at the present time practically four-fifths of the commercial citrus acreage and production are made up of oranges.

Next in importance is the lemon, which comprises nearly all the remaining portion of the commercial acreage and production.

A relatively small acreage is devoted to grapefruit, though the culture of this fruit is being extended more rapidly than any other citrus, especially in the Imperial Valley of California and in Arizona. In these sections oranges seem to be less adapted than grapefruit to the very hot, dry conditions which prevail during the long summers, and new plantings in those localities are composed of continually increasing proportions of the latter fruit. In the Salt River Valley of Arizona the old seedling oranges thrive well, but this fruit is gradually disappearing from commercial shipments in the Southwest largely on account of its normally small size in comparison with that of the standard varieties.

There are a few small orchards of Satsuma and tangerine types of oranges in California, and they usually produce very profitable crops. The culture of both these fruits is being extended slowly, for the market demands for them are somewhat limited. The varieties of the Satsuma type are early ripening and are more resistant than other varieties to low temperatures and other climatic extremes.

Lime trees were planted in a number of places during the early development of the citrus industry, but owing to the extreme tenderness of both the trees and fruits and their frequent injury during periods of low temperature their culture has been largely abandoned. A few trees are still grown in some districts in particularly frost-free locations, to supply local market demands and for experimental study.

The citron of commerce is grown on a very small scale in some districts. An old orchard near Riverside, Calif., produces fair crops under adverse conditions, but the usual lack of profitable demand for the fruit has prevented any growth of the industry.

VARIETIES GROWN IN THE SOUTHWEST

COMMERCIAL VARIETIES

The term "commercial" as here used refers to those varieties which have been proved to produce fruits meeting the market requirements and whose culture has been found to be successful under favorable environmental conditions, so that they have become established on an extensive scale as dependable under normal conditions for the production of profitable crops.

The citrus industry of the Southwest is based upon the culture of only five important varieties—two oranges, two lemons, and one grapefruit. The great advantage of thus limiting commercial production to a few standard and proved varieties has been fully demonstrated.

ORANGE VARIETIES

The early determination of the advantages of the Washington Navel orange, when the fruits of this variety were found to have superior eating qualities, including seedlessness, to possess high color and smooth texture of rinds, giving them an attractive appearance, and to hang upon the trees for a long period in good condition after they became mature, led to the planting of large acreages, which soon resulted in a sufficient production of fruit to furnish the market with regular supplies during the winter and spring months.

After considerable experience with varieties maturing during the time when Washington Navel oranges are not available, the Valencia orange was adopted because it satisfactorily met the market requirements for a complementary variety. With these two varieties oranges are supplied from the Southwest throughout the entire year, the Washington Navel meeting the winter and spring demand and the Valencia meeting the summer and autumn requirements. This condition is largely responsible for the rapid development and commercial success of the citrus industry in the Southwest. The total acreage of Washington Navel and Valencia oranges in the principal producing counties of California is shown in Table 3, compiled by the California Cooperative Crop-Reporting Service.

The Washington Navel orange is believed to have originated at Bahia, Brazil, about 1820, as a bud mutation from the Portuguese variety Laranga Selecta. It was introduced to this country in 1870 through the U. S. Department of Agriculture and was distributed

in California and Florida, but has proved to be unadapted to conditions in the latter State.

The Valencia was received from Thomas Rivers, of London, England, in two importations, one direct in 1876 and the other indirectly from Florida at about the same time. The label had been lost from the Florida trees, and the variety was variously known as "Hart's Late," "Hart's Tardiff," and "Hart," but its identity with Valencia was later recognized, and it is now generally given that name.

TABLE 3.—*Orange varieties in the principal producing counties of California on January 1, 1924, excluding the plantings of 1923*

Variety	Orange orchards (acres)	
	Bearing	Nonbearing
Washington Navel	92,306	4,049
Valencia	79,102	8,305
Miscellaneous varieties	2,840	10

LEMON VARIETIES

The lemon industry in the Southwest is also based upon the culture of only two varieties, the Eureka and Lisbon, which have been found to meet the market requirements satisfactorily. The Eureka lemon was originated by T. A. Garey, a nurseryman at Los Angeles, in 1877, as a selection of one tree from several that had been grown from seeds of Sicilian lemons which were planted by Doctor Halsey in 1858. It is now the variety most extensively grown in the Southwest.

The Lisbon lemon was introduced into California in a number of importations, the first of which were made as budded trees in 1874 and 1875 from Australia.

These varieties differ in their periods of heaviest production and vary somewhat with changes in climatic conditions. In general the Eureka may be said to be a late spring and summer variety, while the Lisbon bears most heavily in the winter and spring. Because Lisbon trees are somewhat more vigorous and have denser foliage than Eureka trees they are considered by some growers to be more resistant to light frosts and to protect the fruit from winds and sunburn to a greater degree. They are also much more thorny than those of the Eureka variety. Typical fruits of the two varieties differ slightly in shape, but there is so much variation in this respect that it is often almost impossible for an expert to distinguish them. In marketing practice no attempt is made to do so, and they are both handled simply as lemons.

GRAPEFRUIT VARIETIES

The commercial grapefruit industry in the Southwest is considered as dating from the introduction of the Marsh variety from Florida in 1890. Previous to that time a number of small plantings of several varieties had been made, but none of them were found to be commercially successful. Planting varieties other than the Marsh has been practically discontinued in this section during recent years, this variety being accepted as the most desirable from the marketing standpoint.

On account of the climatic conditions which prevail in the Arizona citrus districts and in the San Joaquin, Coachella, and Imperial Valleys of California, grapefruit matures very rapidly in those sections and is distributed locally and in western markets during the late fall and early winter. In other sections where grapefruit is grown it ripens more slowly and does not mature until the following spring. Formerly it was the custom in these districts to pick the fruit during the winter months, when it was immature and not fit to eat. During recent years, largely as the result of investigations by the senior writer, the picking of this fruit has been delayed until May or later, when it is fully ripe and possesses superior eating qualities. Under proper storage conditions, with careful attention to maintaining uniformly high humidity, it has been found practicable to hold ripe grapefruit for considerable periods of time,[1] making it possible to supply the market demands for this fruit during the greater part of the year.

STANDARDIZATION OF VARIETIES

The term "standardization of varieties" is here used to mean the systematic selection of buds for propagation from inherently superior parent trees of the most desirable strains, thus eliminating inferior and diverse strains arising by bud variation. The word "strain" is used to designate a group of individuals of a horticultural variety differing from all other individuals of the variety in one or more constant and recognizable characteristics and capable of perpetuation through vegetative propagation.

It has been found in investigations previously reported[2] that bud variations are of frequent occurrence in citrus trees and that through their intentional or (as has been more frequently the case) unintentional propagation they give rise to diverse strains, many of which are inferior to the typical or best strains. It has been demonstrated experimentally and proved commercially that by using fruit-bearing budwood with typical fruits attached from heavy and regular bearing parent trees which have been found to be inherently stable it is possible to propagate uniform trees of the best strains which will produce superior crops of fruit.

The effect of this standardization upon the production of citrus varieties is to increase the yield as well as to improve the quality and commercial grade of the product. In the commercial varieties grown in the Southwest the trees of the stable and best strains are normally more productive and more regular than those of the variable and inferior strains. For example, the trees of the Australian strain of the Washington Navel orange variety produce small yields of undesirable fruits in comparison with the trees of the Washington or best strain under the same cultural conditions.

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[1] Lon A. Hawkins and J. R. Magness. Some changes in Florida grapefruit in Storage. *In* Jour. Agr. Research, vol. 20, pp. 357–373. 1920.

[2] A. D. Shamel, L. B. Scott, and C. S. Pomeroy. Citrus-fruit improvement: A study of bud variation in the Washington Navel orange. U. S. Dept. Agr. Bul. 623, 146 pp., illus. 1918.

——— ——— Citrus-fruit improvement: A study of bud variation in the Valencia orange. U. S. Dept. Agr. Bul. 624, 120 pp., illus. 1918.

——— ——— Citrus-fruit improvement: A study of bud variation in the Marsh grapefruit. U. S. Dept. Agr. Bul. 697, 112 pp., illus. 1918.

———, and C. L. Dyer. Citrus-fruit improvement: A study of bud variation in the Eureka lemon. U. S. Dept. Agr. Bul. 813, 88 pp., illus. 1920.

——— ——— Citrus-fruit improvement: A study of bud variation in the Lisbon lemon. U. S. Dept. Agr. Bul. 815, 70 pp., illus. 1920.

The trees of the Alternate-Bearing strain of the Marsh grapefruit variety bear full crops only every other year, with an average yield which is usually considerably below that of the trees of the Marsh or best strain. The low production in many citrus orchards has been found to be due almost entirely to the presence of trees of inferior strains.

In established healthy orchards the standardization of the varieties planted can be accomplished through top-working the trees of the off strains with buds taken from superior trees of the best strains. In the case of new citrus orchards this standardization is effected by planting only trees grown from buds carefully selected from superior trees of the best strains.

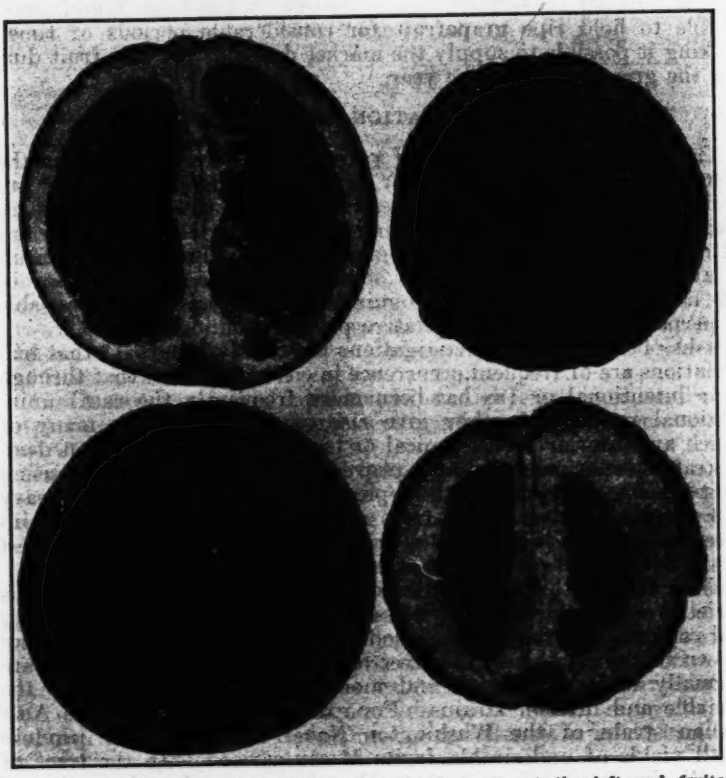

FIG. 3.—Typical fruits of the Washington Navel orange at the left and fruits of the Dry strain produced on a limb sport in the same tree which was grown from a single bud. Propagations from this mutant limb have developed trees bearing similar dry fruits. (Highgrove, Calif., April, 1923)

STRAINS OF THE LEADING VARIETIES

An individual-tree study in several Washington Navel orange orchards in southern California which was begun by the senior writer in 1909 revealed the presence of several diverse strains. Thus far, 13 important strains of this variety have been found, and many

other less marked departures from the Washington strain have been noticed. Descriptions of the important strains of the principal citrus varieties will be found in the publications mentioned in the footnote on page 9. The following are most frequently found in established Washington Navel orchards and are probably the most important ones: Washington, Thomson, Australian, Golden Nugget, Unproductive, Corrugated, and Dry. The Washington is the best of these on account of the productiveness of the trees and the superior commercial and eating qualities of the fruit. The other strains are more or less inferior and are not now being propagated except for experimental purposes. An illustration of one of the least desirable of these strains is shown in Figure 3.

In the Valencia variety 13 important strains arising from bud mutations have been found. Many minor and less frequent varia-

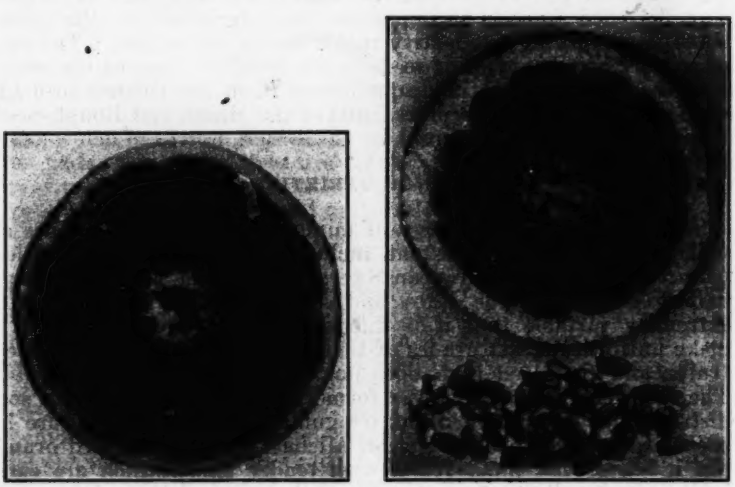

FIG. 4.—Cross sections of typical fruits of the Marsh and Rough-Seedy strains of the Marsh grapefruit, the latter a bud variation from the former. (Highgrove, Calif., July, 1916)

tions have been discovered, but they are apparently of little commercial importance. The following strains are of most frequent occurrence: Valencia, Corrugated, Ribbed, Long, Unproductive, Rough, and Sporting (or Variable). The Valencia strain is the most valuable of these. Its fully mature fruits are of good eating quality, inferior only to the Washington Navel of the oranges of the Southwest. The other strains of the Valencia are inferior for all conditions of culture so far as known. They are of great scientific interest, but of commercial importance only when occurring as mixtures in Valencia orchards.

Among the eight strains of the Eureka lemon which have been classified thus far the most important are the Eureka, Shade-Tree, Dense-Unproductive, Pear-Shape, and Variegated. The Eureka strain is the most productive and valuable, the others being distinctly inferior for commercial lemon growing. The unintentional

propagation of bud variations in the Lisbon variety has given rise to at least six important strains: Lisbon, Open, Dense-Unproductive, Bull, Variegated, and Sporting (or Variable). Of these, the Lisbon is the most important commercially. The trees of this strain seem to be particularly well adapted for growing in regions near the seacoast and are also suited to conditions in some of the interior districts. The other strains are less desirable than the Lisbon and should be eliminated in established orchards through top-working or replanting.

In grapefruit orchards of the Marsh variety seven strains arising from the unintentional propagation of bud mutations have been discovered, of which the following are the most important: Marsh, Alternate-Bearing, Rough-Seedy, Smooth-Seedy, and Unproductive. The trees of the Marsh strain are regularly productive, bearing oblate-shaped fruit with the stem end often slightly sunken. This flattened shape is an important characteristic from the market standpoint, serving to identify the fruits of this strain. The comparatively large number of seeds in the fruits of some of the strains is an important factor in disqualifying them for further propagation. Cross sections of typical fruits of the Marsh and Rough-Seedy strains are shown in Figure 4.

MINOR VARIETIES

Several varieties of oranges of minor commercial importance are still grown to a limited extent, including the Ruby, Maltese Blood (*Malta Blood*), Mediterranean Sweet, St. Michael, and a number of named seedlings. The Ruby and Maltese Blood varieties are so extremely variable that it is difficult under present conditions to make uniform market grades of them. They also bear small, seedy fruits, and their red flesh does not appeal to the general public. The Mediterranean Sweet was formerly a popular variety in some districts, but on account of its irregular production its culture has been largely abandoned. The St. Michael is a fine-flavored orange, but it bears very small fruits with tender rinds which are easily injured in handling, so that most of the trees of this variety have been top-worked during recent years. The Mission seedling was the first orange introduced in the Southwest. Other seedlings adapted to local conditions were introduced from time to time, and a few of them are still grown in some districts. The principal favorable character of the seedlings is their usual regular and heavy bearing even under many extreme climatic conditions, but the normal small size of the fruits is a factor resulting in the gradual top-working or replanting of these orchards.

The Villafranca lemon was very popular in some districts during the early development of the industry. Because the normal yield of this variety is relatively low and it produces its main crop during the most undesirable marketing period, it has been practically eliminated from culture.

The Duncan and Triumph varieties of grapefruit are considered by some growers to be superior to the Marsh, but their high seed content has been largely responsible for their abandonment for commercial culture.

PROPAGATION OF CITRUS TREES

The growing of reliable citrus nursery trees is a highly specialized industry. In the Southwest it is conducted largely by professional nurserymen who, as a rule, confine their work to the propagation of citrus trees alone. A few growers propagate their own trees, selling their surplus to other growers.

Citrus trees are universally propagated in the Southwest by budding on seedling stocks. During the past 10 years fundamental improvements have been made in methods of propagation, among the most striking of which are the use of budwood taken from superior parent trees and the use of carefully selected root stocks. Citrus orchards which have been propagated in this way are made up of trees of uniform size and type and bear heavier crops of more uniformly good fruits than comparative orchards planted with ordinary trees.

The planting of reliable trees or those which are known to be inherently good is a matter of great importance to citrus growers. The term "reliable trees" is here used to mean those which have been propagated from buds taken from superior parent trees on root stocks which have been selected as uniformly desirable for the conditions under which the trees are to be grown. The term "superior parent tree" is used to indicate full-bearing trees which are known to produce regular, heavy, and uniformly desirable crops.

ROOT STOCKS

For all commercial citrus varieties in the Southwest the sour orange has proved to be the best root stock. Adequate supplies of sour-orange seed can be procured from Florida, and a small but increasing supply is available in the Southwest. The seedlings make congenial bud unions, are resistant to gummosis, scaly bark, and other citrus diseases, and are hardy and adapted for growth under the environmental conditions of the Southwest.

Recent investigations in California have demonstrated that seedlings from certain parent sour-orange trees are more uniformly vigorous than those from other trees and have superior habits of growth. It is important, therefore, whenever possible, to select as sources of seed only those trees which have been proved to transmit the desired characteristics to their seedling progenies. Orchard plantings of carefully selected orange seedlings are now being made in southern California in order to provide sources of seed from desirable types of parent trees.

The seeds for root stocks are sown in beds, where they are normally grown for a year. The seedlings are then transplanted or "lined out" in nursery rows about 4 feet apart and spaced about 1 foot apart in the rows, all weak, deformed, or otherwise undesirable ones being discarded. Before replanting the tops and taproots are usually cut back to about two-thirds of their length.

BUD SELECTION

The importance of systematic bud selection in propagating inherently good citrus trees has been demonstrated experimentally and commercially during the past 10 years. In order to make carefully

selected buds readily available to all growers and nurserymen, a bud department was organized as a public service by the supply company of the California Fruit Growers Exchange in cooperation with the United States Department of Agriculture. That office secures and distributes at cost selected budwood from superior parent trees and furnishes information regarding supplies of nursery trees propagated from such buds. From the establishment of that office in May, 1917, to July 1, 1924, it distributed 2,850,000 selected buds to many of the citrus sections of the world. The success of this undertaking, which has been self-supporting from the start, shows that nurserymen and growers appreciate the value of systematic bud selection in improving citrus production. A description of this cooperative work is given in the Yearbook of the United States Department of Agriculture for 1919.[3] Improvements in the methods of bud selection are being developed constantly as a result of scientific investigation, but the fundamental principles underlying these methods will be briefly described.

The basis of bud-selection work is the determination of inherently superior parent trees as sources of budwood for propagation. The selection of such trees is based upon individual-tree performance records, intimate tree knowledge, and progeny tests. While records of the quantity, commercial quality, and regularity of production are important considerations, the uniformity in type of fruits, the absence of marked variations, and a knowledge of the characteristics of the various strains gained through wide orchard experience are also of special importance in carrying out this work.

The individual-tree performance records should be made from a large number of trees in full bearing in orchards where the environmental conditions are uniformly good and that are known to produce large crops of fruit of the highest commercial quality. To be of the greatest value these records should cover a period of not less than four years of normal fruit production.

Trees having a production that is otherwise satisfactory but which show variations in fruit or foliage should in no case be selected as sources of budwood for commercial propagation. Experimental tests and orchard experience have shown that citrus trees grown from buds taken from the normal growth of trees which have even a single branch bearing variable crops are likely to produce variable crops of inferior value.

Performance records of progeny trees grown from buds taken from superior parent trees are the best and most reliable indication of the stability of these trees, and they determine those trees that are prepotent in transmitting their desirable characteristics. In California, where extensive progeny tests have been conducted for several years, it is now possible to select superior parent citrus trees on the basis of progeny performance.

The cutting of budwood for propagation from superior parent trees should be done as nearly as possible at the time when the buds are to be used, but if necessary the wood can be stored for several months under proper conditions of temperature and humidity.

Fruit wood only should be cut for budwood, and, if possible, fruit-bearing wood should be selected with typical fruits attached.

[3] A. D. Shamel. Cooperative improvement of citrus varieties. U. S. Dept. Agr. Yearbook, 1919, pp. 249–275, illus. 1920.

as shown in Figure 5. This precaution is desirable because the fruits attached to the bud sticks make it possible to avoid branches bearing variable fruits and to be certain that the budwood does bear superior fruits, indicating the type that may be expected from the trees grown from these buds. The immature wood back of the fruits is most desirable for propagation. While such bud sticks are usually smaller than those from older growth or from the more vigorous vegetative branches, commonly called suckers, they give results equally good, if not better. Figure 6 shows a Eureka lemon nursery propagated in this way and illustrates the satisfactory growth and early-fruiting characteristics of such trees.

FIG. 5.—Typical fruit-bearing Valencia orange bud stick, showing the type of budwood secured for propagation

BUDDING

Seedlings are commonly budded in the spring during the period of growth from March to June, inclusive, or at the time of fall growth, which usually comes in September and October, but it can be done at any time when growth is active and the bark slips easily.

Relatively high budding, from 6 to 10 inches above the ground, is now generally preferred, because there is less danger of the bud unions being covered with soil with the subsequent development of adventitious roots or of gummosis or other troubles of the scions after such trees are set in the orchard. Seedlings which have made a satisfactory growth so that they can be budded after one year in the nursery are considered most desirable.

The usual method of budding citrus in the Southwest is by the use of shield buds inserted in inverted T-shaped incisions. The cut bark is then bound in place by wrapping with strips of waxed cloth, which are removed after two or three weeks, when the buds have united with the stocks. When fall budding is practiced the dormant buds are left wrapped until the following spring. At the time the wraps are removed or soon afterwards the stocks are cut off about 6 inches above the bud. A recent test has shown that if the trees are lopped instead of being cut off the new growth is much more rapid and vigorous.

GROWING NURSERY TREES

The training of nursery trees includes staking them, heading them at the proper height, and spacing the framework branches. Lath stakes are driven into the ground about 2 inches from the base of the seedlings on the same side as the buds, and the growth from the

FIG. 6.—Nursery trees of the best strain of the Eureka lemon variety two years after budding on sour-orange stock. These young trees blossomed and small fruits developed while still in the nursery row. This is characteristic of the young trees propagated by the use of improved methods

inserted buds is trained to grow straight by being tied every few inches. When the trees have reached a diameter of about half an inch the seedling stubs are cut back with a sloping cut as close to the young tree trunks as possible and the wounds covered with grafting wax.[4]

[4] A very satisfactory grafting wax is made of equal parts of beeswax and rosin. For inarching 2 parts of beeswax to 1 of rosin are used. Others use beeswax alone for all purposes. A satisfactory formula which is less expensive is as follows: Rosin, 4 pounds; beeswax, 1 pound; tallow, 1 pound (or linseed oil, 1 pint). Melt together in a kettle. In hot weather use more rosin. Apply warm with a brush.

When the trees are about 3 feet high they are cut back to 28 to 30 inches. There is an increasing partiality among growers for high-headed trees, some preferring to have them 36 inches high. A number of lateral branches will then develop along the upper part of the trees, from which three to six spirally spaced ones are selected to form the framework of the tree, all other growth being carefully removed.

At the time of transplanting, the main branches are cut back to 8 or 10 inches in length, to check excessive transpiration during the moving operations and to compensate for the roots cut off in digging the trees. There is an increasing preference for trees which were in the nursery for a year as seedlings and which have made a sufficient growth to be transplanted one year after budding.

DIGGING NURSERY TREES

Digging nursery trees for transplanting is done during either spring or fall, the spring usually being considered best for this work. Balling has been the general practice in nursery transplanting, but the bare-root system is now used to a considerable extent. The chief disadvantages of balling are the heavy weight of such trees and the additional expense of digging and moving them.

If the trees are not to be planted at once they should be moved to a lath house or other shelter where they can be kept moist and protected from the sun and wind. If they are to remain unplanted for a considerable time they should be set on a layer of dampened sawdust with additional sawdust thrown around and between them and sprinkled from time to time.

The bare-root method of transplanting nursery trees is particularly advantageous when they are to be moved only a short distance and when all operations have the careful supervision of experienced men. The roots must be kept covered with wet sacks or other moist material, and it is often desirable to pack the trees in crates with the roots covered with dampened moss.

LOCATION OF THE ORCHARD

In the selection of a desirable site for a citrus orchard care should be taken to choose a location relatively free from frosts and heavy winds, with an adequate supply of good water and preferably with a loam type of soil having good underdrainage and free from alkali dangers.

Liability to frost damage is one of the most important factors in the consideration of an orchard site. The distribution of frosts in the past few years has indicated that no general locality can properly be considered entirely free from this danger, but in most sections there are more or less restricted areas which on account of various local conditions of relative elevation, natural protection, or some other favorable circumstance are least liable to be injured during periods of low temperatures. In growing lemons, the relatively frost-free sections are especially desirable, as both the trees and fruits are more tender than oranges.

Heavy and extremely dry northerly winds are rather common in some regions of the Southwest during certain seasons of the year, and experience has shown that such areas should not be planted to citrus fruits.

DEVELOPMENT OF THE ORCHARD

PREPARATION OF LAND FOR PLANTING

The method of preparing the land for planting depends to a large extent upon its nature and previous history. This discussion is confined to the preparation of virgin land or land upon which legume, grain, or similar crops have been grown, but where orchards have not previously been planted.

Virgin or rich soils usually do not need any particular treatment after they have been cleared. Where legume crops have been grown for some time the soil is normally in good condition, but if the land has been cropped with barley, wheat, or other grains it is frequently advisable to grow a legume or other green-manure crop and plow it under to improve the soil tilth and fertility.

Formerly it was the common practice to level uneven land before planting by scraping off the higher spots and filling the lower areas, so that the trees could be set in straight rows and properly irrigated, but during recent years such scraping is usually avoided by contouring uneven land, that is, running the tree rows with the contour levels. Naturally some leveling may be necessary in laying out contour rows to provide for the proper flow of irrigation water, but with this method of planting such work is reduced to the minimum.

To provide the most desirable conditions of soil tilth for the young trees and cover crops the area should be plowed and cultivated before the trees are planted. If they are to be set in the spring, as is usual, rather deep plowing after the winter rains is advisable, followed by thorough cultivation. A legume cover crop should be planted, preferably after the trees have been set, to further improve the soil conditions.

In shallow soils or those having a heavy subsoil it is frequently thought advisable to supplement the plowing by subsoiling or by blasting in the holes where the trees are to be set. The desirability of these practices depends upon the local soil and especially the subsoil conditions, oftentimes varying in different parts of the same orchard.

The term "ridging" is used to mean the building up of low ridges upon which the young trees are to be planted. The desirability of this practice depends upon local soil and related conditions, and its advisability should be determined by the experience of growers having similar orchard conditions.

In addition to other fertilization it is usually desirable to bury liberal quantities of well-rotted stable manure or other forms of organic fertilizers in or near the holes where the trees are to be planted. These should be well mixed with the soil or placed below the roots of the trees to prevent injury to them from the heating or other action of the manures.

The irrigation system should be installed before planting the trees, if possible, as it is important that they be watered as soon as they are set.

PLANTING THE TREES

Spring or early-summer planting is generally preferred for citrus trees in the Southwest, but this work may be done during the greater part of the year. Spring-planted trees usually continue growth with only a slight check, and it is less expensive to protect the young trees from possible frost damage during the winter in the nursery than in the orchard.

Planting plans vary somewhat, but the square system is the one in general use, because it permits orchard operations to be carried on most conveniently. Orange and grapefruit trees are usually spaced in rows from 24 to 26 feet apart, with the trees from 20 to 22 feet apart in the rows. This provides for 90 to 76 trees per acre. With lemons the rows are commonly spaced from 22 to 26 feet apart and the trees from 18 to 20 feet apart in the rows, which provides for 110 to 84 trees per acre.

FIG. 7.—A recently planted Valencia orange tree, showing the heading back of the framework branches and the trunk protected from sunburn with a newspaper wrapper. (Santa Paula, Calif., May, 1922.)

On uneven orchard sites where contouring is necessary it is sometimes found advisable to build terraces to prevent soil washing during rainy seasons. The expense of building and maintaining terraces and of cultivating on them is relatively high, and this fact should be considered before making such plantings.

After the orchard site has been surveyed stakes should be set marking the spots where the trees are to be planted. A convenient method for locating the trees accurately includes the use of a planting board about 4 feet long with a notch at the center and one at each end. The center notch is placed over the marking stake, and pegs are then driven into the ground at the notches in the ends of the board. The board and marking stake are then removed, leaving the end pegs as guides for digging the hole and setting the tree.

The holes should be dug about 3 feet in diameter and 2 feet deep, keeping the topsoil separate from that below and loosening the soil in the bottom of the hole to the depth of the shovel. Sufficient topsoil should then be thrown into the hole so that the bud union of the tree will ultimately stand as far above the ground after planting as it did in the nursery, allowing for the settling of the soil. The planting board is placed over the hole with the pegs in the end notches and the tree trunk in the center notch, and the hole is refilled, using the remainder of the topsoil around the roots of the tree. If balled trees are planted, the cord should be cut and the corners of the sacking spread out and covered with the last few shovelfuls of earth.

Planting should begin at the upper ends of the rows, and water should be immediately applied in furrows encircling the trees. The tree trunks should be protected from sunburn and other injuries by wrapping them with newspapers, as shown in Figure 7, or by other protectors.

FERTILIZATION

The improvement of soils through systematic fertilization has received increasing attention during recent years, and at the present time this problem is one of great importance and interest to citrus growers. It is now believed that the chief value of fertilizers for citrus soils in the Southwest lies in their nitrogen and organic content.

The methods of soil improvement in common use include (1) the use of organic manures, (2) the application of commercial fertilizers furnishing organic or inorganic supplies of nitrogen, (3) the growing of cover crops in the orchards, (4) the mulching or covering of orchard soils with organic materials, and (5) resurfacing orchard areas with fresh soil.

On account of soil variability in different orchards, often in the same orchard, soil improvement becomes an individual orchard problem, and no definite rules can be given without considering the nature of the local soil and its response to fertilizer treatments, but certain principles will be briefly discussed which seem to apply to orchard conditions in the Southwest as a whole. Established methods of fertilizer application should be followed consistently until some other method has been proved to be more successful under local conditions.

MANURES

The principal kinds of manures adapted for use in citrus orchards include stable manure, alfalfa hay, bean straw, and guano.

The term "stable manure" is here used to include the manures of horses, cows, sheep, goats, and poultry or other domestic animals. The composition and value of these manures vary with many conditions, including the kind and age of the animals, their feed, and particularly the conditions under which the manures are collected, handled, or stored.

In addition to knowledge of the chemical composition of manures it is important to know that they are free from noxious weed seeds or other injurious substances and from excessive quantities of shavings, soil, water, or other adulterants which add to their weight but not to their value. Ordinarily, good horse manure contains about 0.5 per cent and cow manure 0.75 to 1 per cent nitrogen. The only safe way to buy manures is on the basis of their composition as revealed by careful chemical and physical analyses, the cost of which is fully justified as a legitimate item of fertilizer expense.

Many successful citrus orchardists apply coarse organic manures during the fall or early winter, so that they will have become partially or wholly decomposed before active growth begins in the spring. Others apply the manure in the late winter or early spring, frequently at the time of spring plowing after the winter rainy period has passed.

On account of the limited supplies of stable manure and the greatly increased use of it in citrus orchards during recent years, its cost has risen rapidly, until it has become necessary to look for other sources of organic fertilizers. As a result of this condition alfalfa hay, bean straw, and guano have come into more general use. While these materials are more uniform in composition than stable manure, it is very desirable and a common practice to buy them on the basis of their analyses for nitrogen and organic matter.

Alfalfa hay contains about 2 per cent nitrogen and has been so extensively used in fertilization in recent years as to cause a considerable rise in its price. The poorer or damaged grades are satisfactory for this purpose and are used when they can be obtained. Both the baled and loose hays are sometimes chopped or sawed, in order to facilitate their distribution in the orchard, which is often done with modified manure spreaders.

Bean straw was at one time used extensively in citrus orchards, but the bean growers now apply it so generally to their own lands that the commercial supply has become very limited.

Guano is considered of great value for citrus soils, but its use is restricted at the present time by its limited availability.

The quantity of manure to be used for most economical results depends upon a number of variable conditions. For citrus trees in full bearing an application of manure containing nitrogen at the rate of about 1½ to 2 pounds per tree each year is generally considered adequate in most southwestern orchards, when used in connection with other nitrogenous fertilizers supplying a total of from 3 to 4 pounds of nitrogen per tree.

The broadcast and the furrow methods are commonly used for applying manure.

Broadcasting manure.—Until recent years manures have ordinarily been scattered broadcast and plowed under or mixed with the surface soil by disks or cultivators. An apparent advantage of this method is that the fertilizer is distributed over all the spaces between the trees, and soils in poor physical condition as a result of deficient organic matter are often improved in tilth by this treatment. An objection to this method is that in many instances the broadcasted fertilizers are allowed to remain exposed on the surface of the soil until much of their value has been lost, but this loss can be largely prevented if the freshly distributed manures are promptly plowed or disked into the soil.

Furrow-manure method.—A recent and more economical method of applying organic fertilizers, called the furrow-manure method, which was introduced and developed by the senior writer, has now come into general use in citrus and other orchards of the Southwest. This method provides for the distribution of manures or other fertilizers in furrows from 8 to 14 inches deep alongside the trees. Plows of the middle-burster type are generally used in making the furrows, as shown in Figure 8. The furrows for the first season may be run along both sides of the trees near the drip of the branches in the same direction as the flow of the irrigation water. They may be similarly located the second season, but at right angles to those of the first year if the orchard planting is such as to permit cross plowing. The third year the furrows may

be made parallel to those of the first year but nearer the middles of the tree rows, and similarly placed the fourth year parallel to those of the second year. The arrangement of the furrows for later applications will depend upon circumstances, but in some cases growers have successfully repeated this plan of the first four years.

The furrows made during any one day should be filled and covered the same day or as soon thereafter as practicable. For young trees it is generally considered necessary to distribute the manures only alongside the trees, but with large trees it is desirable to fill the furrows for their entire length. The covering of the furrows is usually done by a plow run on each side of the filled furrows, so as

FIG. 8.—A home-rigged plow of the middle-burster type making a deep furrow for the application of manure. Note the lumps of hard plow sole which were broken up by the plow. (Corona, Calif., September, 1922)

to throw the soil over the manure. The furrows left by this operation may be used for subsequent irrigations if they are in the direction of the irrigation flow.

The furrow-manure method seems best adapted for use in the fall, winter, or early spring. It is often used for the distribution of organic fertilizers just before the cover-crop seed is sown in the fall or at the time of spring plowing, when the cover crops are turned under.

The desirable quantity of manure to be applied in this way depends upon local conditions, but with full-bearing trees an annual application of 5 to 10 cubic feet per tree of good stable manure or its equivalent in other organic fertilizers has given excellent results. As a rule the manure distributed in furrows has given much

better results in improved tree conditions than a larger quantity broadcasted in the ordinary way.

These deep furrows break up compact soils and plow soles, and the decomposing fertilizers markedly improve the physical condition of the feeding-root zone in the soil. The bunched manure tends to increase the water-holding capacity of the soil in the feeding-root area and to prevent the development of the impenetrable plow-sole condition directly below the zone of cultivation. Where cover crops are not grown it may occasionally be advisable to distribute organic fertilizers broadcast, in order to improve the physical condition of the soil throughout the orchard.

COMMERCIAL FERTILIZERS

Commercial fertilizers are here considered as concentrated organic or inorganic plant foods. No attempt will be made to discuss this subject other than to call attention to fertilizers which are commonly thought to be important in promoting citrus tree and fruit development and to others which are believed to be injurious.

Commercial sulphate of ammonia usually contains about 20 per cent nitrogen in a readily available form. The method of application which has given the best results is to distribute it three times during the spring months in the irrigation furrows near the drip of the branches, using from 1 to 3 pounds per tree each time, depending upon the size of the trees. The first application can be made just before the blooming period, the second about a month later, and the third about 30 days after the second. These applications are thought to prevent excessive dropping of the fruits, but the repeated use of large quantities of sulphate of ammonia on certain heavy soils is believed to be injurious.

Dried blood is one of the richest organic nitrogenous fertilizing materials and decomposes rapidly in the soil. The so-called red dried blood contains from 13 to 14 per cent nitrogen and the black grade from 6 to 12 per cent. Both grades contain considerable phosphoric acid, frequently as high as 4 per cent. Ordinarily, an annual application of 10 to 15 pounds per tree is considered adequate for full-bearing citrus trees, and it is usually applied at the time of the late-winter or early-spring plowing, so that it will be turned below the zone of subsequent cultivations. If used at other times care should be taken to apply it so deep that it will not be disturbed during cultivation. Where the furrow-manure system is used dried blood is often applied in the bottom of the furrows.

Cottonseed meal is a valuable nitrogenous fertilizer, ranking with blood in the availability of its nitrogen. When properly prepared and free from hulls it contains about 6 per cent nitrogen. When fed to animals the manure resulting therefrom is particularly valuable for the highly mineralized soils common in many of the citrus orchards of the Southwest. It should be applied in a similar manner and during the same season as dried blood.

Tankage is a highly nitrogenous product, consisting largely of animal wastes from abattoirs, and is likely to be variable in composition. Two distinct kinds are marketed—high-grade tankage, ranging from 9 to 12 per cent nitrogen with a little phosphoric acid, and low-grade tankage, containing from 4 to 9 per cent nitrogen and

3 to 12 per cent phosphoric acid. This product is applied in varying quantities, depending on its composition and the age of the trees, frequently from 10 to 15 pounds per tree being used. It is distributed and incorporated in the soil at the same time and in a manner similar to dried blood.

Garbage tankage as distinguished from other tankage consists of hotel and household garbage treated for use as a fertilizer. It has been reported that in some instance such tankage has contained table salt or other injurious substances, but modern methods of treating the garbage have largely removed the difficulties connected with its use.

Commercial nitrate of soda contains about 15 or 16 per cent nitrogen. While it is one of the most economical sources of nitrogen for fertilizer purposes, its use in many citrus orchards of the Southwest has been largely discontinued during recent years on account of the apparently injurious effect of its sodium element, which in certain soils is said to result in a mottled-leaf condition.

Calcium nitrate has recently come into quite common use as a commercial form of nitrogenous fertilizer. Usually it contains from 13 to 18 per cent nitrogen. From 10 to 15 pounds per tree, frequently applied in fractional quantities at three separate distributions during the spring months, is ordinarily thought to be adequate for full-bearing trees.

Dried or ground fish varies in composition according to its source. If composed of the offal from packing or canning plants it varies so widely that analyses of each lot are needed to determine its fertilizing value. If derived from pomace resulting from the extraction of the oil of menhaden it generally contains from 7 to 8 per cent nitrogen and from 6 to 8 per cent phosphoric acid. About 25 pounds per tree turned under at the time of winter plowing or applied in manure furrows is considered adequate when used with manure or other similar organic materials.

Bone meal has a phosphoric acid content of 22 to 26 per cent, with from 2 to 3 per cent of nitrogen. It is a valuable source of phosphoric acid where that element is needed for orchard fertilization.

Lime or calcium oxide is usually produced by burning limestone. On acid soils and with some other unfavorable soil conditions its use is advisable, but ordinarily southwestern citrus soils are believed to contain sufficient lime.

Experience seems to indicate that satisfactory results are obtained by the application of fertilizers, partly organic and partly inorganic, supplying nitrogen at the rate of about 300 pounds per acre for trees in full bearing. The organic fertilizers in the form of manures should be applied in the fall or winter and the inorganic fertilizers in two or three distributions in the spring. Peculiar conditions of soil may modify this recommendation both as to quantities and kinds of fertilizers, but the large number of successful orchardists following this general practice warrants its acceptance as fundamentally correct.

COVER CROPS

Cover crops are divided into the two general classes of winter and summer crops. The purposes of the winter crop are to protect

the soil from washing or leaching, increase its fertility, improve its physical character, and supply other beneficial soil influences. Some growers believe that certain disadvantages, such as the lowering of the atmospheric temperature on cold nights and the competition of the cover-crop plants with the trees for water and plant food, outweigh the advantages claimed for the cover crop, but recent studies indicate that during cold weather there is little difference in the minimum temperatures in orchards, with and without cover crops and that when turned under in the late winter or early spring no injurious effects from competition occur.

The most successful legumes for winter cover crops in the Southwest are purple vetch (*Vicia atropurpurea*) and yellow sweet clover (*Melilotus indica*). Purple vetch is now believed to be the most valuable plant for winter growth in citrus orchards, and adequate supplies of its seed are available. This seed is usually sown at the rate of about a bushel per acre when the land is prepared for the August or September irrigation. After germination the plants grow rapidly even during cool weather, so that a large tonnage is produced by the time the late-winter or early-spring plowing is done. Melilotus seed is sown in the same manner as purple vetch, but only about 20 pounds per acre is used.

The supply of irrigation water is generally the limiting factor in growing summer cover crops in citrus orchards. Where water is abundant and other conditions are favorable, it is believed that such crops not only add to the soil fertility but that they also tend to prevent considerable loss of young fruits by the so-called "June drop" through improving atmospheric conditions in the orchards. Of these crops several varieties of cowpeas (*Vigna sinensis*), including the Whippoorwill, are the most commonly used, but alfalfa (*Medicago sativa*), broad beans (*Vicia faba*), Lima beans (*Phaseolus lunatus*), and other legumes are grown for this purpose.

INTERCROPPING

In certain sections, particularly near the coast, the growing of Lima beans and other vegetables between the tree rows in young orchards is successfully practiced. The conditions under which this plan succeeds include a rich soil, abundant water supply, and relatively high atmospheric humidity. In interior sections with higher summer temperatures, comparatively low relative humidity, and a limited water supply intercropping has generally been found undesirable.

MULCHING

The term "mulching" is here used to define the use of hay, straw, or other organic materials for covering orchard soils. There are at least two methods of applying organic mulches: (1) By broadcasting over the soils, and (2) by piling in shallow basins under or around the trees. With the broadcasting method irrigation is carried on as usual in furrows under the mulch, while in the second method the irrigation system is arranged so as to flood the basins. This practice has generally proved impracticable in citrus orchards except under certain peculiar conditions, because rodents of various

kinds are likely to nest in the mulches and seriously injure the bark or roots of the trees, and the costs of maintaining the basins and mulches are usually very high.

RESURFACING

The resurfacing or mulching of shallow orchard soils with fresh soil has proved profitable in a number of instances. Recent experience has shown that in orchard areas where the original surface soil was scraped off in leveling the land or where the topsoil has been washed away resurfacing has given very beneficial results. An important factor in this work is a convenient source of fresh soil, so that the hauling cost will not be excessive. Downhill hauls and mechanical loading and dumping devices reduce costs, and the work may be done when regular orchard activities are slack.

The fresh soil should be applied to a depth of about 4 to 6 inches, care being taken to keep it from the tree trunks. Fertilization should not be discontinued in the treated areas, although its need may be lessened for a year or so. The advisability of resurfacing should be determined by treating a small area before the practice is adopted throughout an orchard.

CULTIVATION

The common method of cultivation is to plow the ground before or as soon after the winter rains as possible, sometimes as early as January but more frequently during February or March, and to cultivate the soil after each irrigation until the fall cover crop is sown. Moldboard or disk plows are used for the early plowing and stiff-shank, spring-tooth, disk, or other harrows and drags are used for later cultivations. If weeds develop under the trees it may be necessary to remove them with hoes.

Orchards should be cultivated as soon as practicable after irrigation, for without such cultivations many soils, particularly those of a heavy nature, become baked and cracked, resulting in the loss of moisture and the development of other unsatisfactory soil conditions. After the irrigation furrows become dry enough to prevent puddling, it is ordinarily a good plan to use a smoothing harrow or drag to scratch the surface lightly and break up any crust that may be forming, a second cultivation following in a few days to stir the soil thoroughly.

In many irrigated citrus soils in the Southwest a hard and impervious condition known as "plow sole" develops a few inches below the surface during the summer months to such an extent as seriously to hinder or prevent the free circulation of air and the penetration of irrigation water. This condition is believed to result from the practice of plowing or cultivating at about the same depth continuously. Tests made with a soil auger, preferably shortly before irrigations, will indicate the development of the plow sole. As a result of this condition the roots receive insufficient moisture, causing wilting of the foliage, particularly during periods of low atmospheric humidity, and checking both fruit and vegetative growth, while in extreme instances the trees become partially defoliated and much of the fruit drops.

Generally the plow sole can be broken up with special stiff-shanked cultivators or by running a subsoil plow midway between the rows, so as to do minimum injury to the tree roots. Lumps of hard plow sole broken up by a furrow manure plow can be seen in Figure 8.

IRRIGATION

The citrus tree, being an evergreen, uses soil moisture constantly but in varying quantities during different seasons. In most instances the irrigation supply is from streams or wells controlled by water companies or associations of growers, but in some cases it is

FIG. 9.—Straight irrigation furrows supplied with water from an open concrete ditch. (Corona, Calif., August, 1922)

developed from privately owned wells or other sources. The purity of all irrigation water should be carefully determined, especially with regard to the presence of injurious salts or alkalis.

The Southwest is a semiarid region, where the annual rainfall is unequal to the needs of citrus trees and is largely confined to the winter months. Additional water must be supplied during the period of little or no rain. Bearing citrus trees in the Southwest require from 35 to 45 acre-inches annually, depending largely upon the age of the trees and the soil and climatic conditions. As the average annual rainfall in most citrus districts is only from 10 to 25 inches, irrigation must be depended upon to supply the remainder.

If winter or summer cover crops are grown, additional water must be supplied in order to meet their requirements without interfering with the moisture supply of the trees. Where wells are depended upon they should be sufficiently deep to insure a supply during consecutive seasons of possible drought.

Irrigation is ordinarily begun from four to eight weeks after the last heavy winter rain and is repeated about every 30 or 40 days with an application of 3 to 5 acre-inches each time until the rains begin again. In some districts citrus trees require irrigating nearly every month in the year, but in most sections from five to nine irrigations are usually sufficient. Recent experience indicates that on some soils more frequent irrigations are desirable, with smaller quantities of water at each application. It has been determined that it is important to maintain optimum moisture conditions in the first 3 or 4 feet of soil, the feeding roots being largely distributed in the first 2½ feet. An excess of water which penetrates below this depth is usually lost and is of no benefit to the trees or the soil except when it is necessary to drive down injurious salts.

During recent years many of the leading growers have adopted the practice of basing the length of the intervals between irrigations and the quantity of water applied at each irrigation upon a series of systematic soil-moisture determinations throughout their orchards. In these tests the wilting coefficient and the water-absorbing power of the soil are determined, and the system of irrigation is planned so as to maintain the moisture condition in the feeding-root zone as near the optimum as practicable. It is believed that a reorganization of the present irrigation methods based upon the requirements of the trees and the soil-moisture conditions in individual orchards is of fundamental importance in maintaining and developing the citrus industry in the Southwest.

Irrigation water was first conveyed in open dirt ditches and canals and by wooden viaducts. These were gradually supplanted by open concrete-lined canals, which are now being replaced by underground steel or concrete pipe lines, but all these methods are still in use. Concrete pipes are considered most economical and are most commonly used, but steel pipe is frequently used for main lines where the pressure exceeds 10 or 15 pounds per square foot.

After the water reaches the orchard it is taken from the main pipe line and distributed either through open concrete flumes, as shown in Figure 9, or by underground pipes to each tree row. Open flumes are provided with small gates through which the water flows directly to the irrigation furrows. Such flumes are objectionable, because they obstruct the movement of orchard tools, are easily clogged with rubbish, and are subject to frequent breakage. Underground pipe lines are laid deep enough to be out of the way of cultivation implements and are provided with concrete hydrants or standpipes for each row of trees, as shown in Figure 10. These hydrants are usually fitted with valves for regulating the flow of water into them and have adjustable gates through which the water flows to the furrows.

From four to eight furrows are ordinarily made between each two rows of trees with a special furrowing implement, and additional furrows are often zigzagged in order to wet the soil between the trees in the rows. The proper length of run of irrigation water depends upon the type of soil and the slope of the land. Runs of 300 to 400 feet are preferable in most soils, but in heavier ones or those having a heavy clay subsoil runs of 600 to 800 feet are sometimes used satisfactorily.

The water should be applied for 24 to 72 hours, a 48-hour application being generally used. The flow should be so regulated that the water reaches the bottom of the furrows in about one-fourth the time of the total application. Further details concerning irrigation practices in citrus orchards can be found in Farmers' Bulletin No. 882, Irrigation of Orchards.[8]

The cost of irrigation water varies from a minimum of about $1.50 per acre annually on some of the original Spanish land grants to as much as $50 to $75 where the water is expensive and considerable pumping is necessary. The expense for water and irrigation labor commonly runs from $15 to $25 per acre for oranges and $30 to $40 for lemons.

FIG. 10.—Irrigation hydrant from buried pipe line showing gates through which water is admitted to the furrows. (San Dimas, Calif., August, 1922)

PRUNING

The training of citrus trees begins in the nursery when the young trees are headed. Other pruning of young trees of productive strains should be avoided, aside from the training of the main limbs and the removal of crossed branches or other objectionable growth. It has been demonstrated that the early fruiting of young citrus trees does not interfere with their later growth or development.

The pruning of older trees includes the training of suitable growth for framework limbs and the removal of suckers or other objectionable branches. Horizontal or drooping growth and fruit spurs should be allowed to set fruits undisturbed. The cutting back of such branches stimulates continued vegetative growth and delays fruit production.

[8] Fortier, S. Irrigation of orchards. U. S. Dept. Agr., Farmers' Bul. 882, 40 pp., illus. 1917.

Two methods of training framework branches are commonly practiced, one resulting in what are termed vase-shaped and the other in so-called bowl-shaped trees. By the vase-shape method the main upright limbs are allowed to grow undisturbed except for essential thinning of interfering growths, resulting in rather tall, upright-growing trees with more than ordinary strength of framework.

By the bowl-shaped method the large inside branches are cut out and the main framework limbs occasionally cut back. These limbs develop new branches, two or more of the outside ones being saved and the remaining upright-growing ones being removed, care being taken not to disturb the horizontal or drooping branches. The new framework branches in turn are cut back when they reach 3 or 4 feet in length and the new growths trained as before. In this way a spreading and open, or bowl-shaped, tree top is secured, resulting in rather low, open, and spreading trees. Such trees are more conveniently picked and more easily fumigated and sprayed than the taller vase-shaped ones. The best method of pruning the individual tree will depend upon the variety, environmental conditions, and local experience.

The best season for pruning is usually during the late winter and in the spring. Ordinarily the spring months are most suitable for this work, but it can be carried on for a longer period if necessary. Care should be taken to avoid pruning during the late fall or early winter, when new growth following the pruning is likely to be injured by dry winds or low temperatures. Pruning during or just following the blooming period is thought to reduce the crop of the succeeding season. Large pruning cuts should be painted over with grafting wax, asphaltum, or some similar material immediately after pruning.

Severe pruning of healthy citrus trees of the most desirable strains is unnecessary and usually causes a reduction of the crop about in proportion to the severity of the pruning. In an orchard test conducted by the writers, severely and moderately pruned Washington Navel orange trees produced less fruit, with no improvement of commercial quality, during a period of eight years following the pruning, as compared with unpruned trees in the same plat.

Citrus trees should be inspected at least once each year and given such pruning as may be necessary. Each tree presents an individual problem and should be treated accordingly. As a rule, there is greater danger of loss and damage by overpruning normal citrus trees than from a lack of pruning. Details regarding methods of pruning citrus trees are given in Farmers' Bulletin No. 1333, Pruning Citrus Trees in the Southwest.[6]

CARE OF INDIVIDUAL TREES

The care of individual trees includes renewal, top-working, replanting, transplanting, treating diseased, girdled, broken, or otherwise injured trees, and similar activities. On most of the larger citrus orchards in the Southwest there is now at least one man whose duty it is to attend to work of this nature, and experience has proved

[6] A. D. Shamel, C. S. Pomeroy, and R. E. Caryl. Pruning citrus trees in the Southwest. U. S. Dept. Agr., Farmers' Bul. 1333, 31 pp., illus. 1923.

this plan to be profitable. In small orchards the grower can usually do this work himself.

Systematic individual-tree performance-record work or tree-estimate data are essential to the intelligent care of the tree in many cases. Individual-tree numbers make it possible to record the location of trees needing attention, and the performance-record data enable the grower to determine accurately those trees which should be top-worked or replanted.

SECURING INDIVIDUAL-TREE PERFORMANCE RECORDS

The objects of individual-tree performance-record work include: (1) Securing definite information on the results of variations in soil or cultural practices and care of the individual tree as the basis for the introduction and use of improved methods, (2) locating superior parent trees as sources of budwood for propagation, (3) determining inferior trees for top-working or replanting, and (4) comparing the behavior of different varieties, strains, or progenies.

Individual-tree performance data normally include records of the yield and the commercial quality of the fruit of each tree with descriptions of the foliage and fruit characteristics. For commercial purposes these data need to show only the number of boxes of fruit that are produced by each tree, together with notes on any unusual condition of fruits or growth, such as the occurrence of striking bud variations, disease or malnutrition troubles, and pest or other injuries.

In the case of young orchards it is often desirable to start individual-tree records as soon as the trees begin to bear, in order that undesirable trees may be replaced with a minimum loss. The records should be continued for several years, as, for example, four or more normal years. While records for two normal seasons supply valuable information, the value of these data increases rapidly with additional records, and a 4-year period is considered to be the minimum from which reliable conclusions can be drawn.

The important considerations involved in carrying on individual-tree performance-record work are the use of an individual-tree numbering system, the organization of the picking work so that each tree is picked separately, and the adoption of a systematic plan of recording the individual-tree yields and other observations.

In the extensive work now under way in California it has been found advisable to give each tree a number of three parts as, for example, 2–13–8, meaning block 2, row 13, and tree 8 in the row, always basing this arrangement on some fixed landmark, such as the irrigation heads. In small plantings it is usually unnecessary to use a block number. This tree number fixes the identity of each tree for observations over an extended period, and by it any tree may be found without difficulty. The figures are usually put on the lower part of the tree trunk with white paint in a vertical column, and they should always be placed in the same relative position.

The picking boxes should be distributed so that the crop of each tree is kept together until its record is ascertained. In some cases the estimated number of boxes is distributed to each tree, as shown in Figure 11, while in other instances the boxes are set in rows in such a way that the crop of each tree can be identified and studied.

The number of boxes of fruit produced by each tree is usually recorded by the picking foreman on blank forms adapted for this work. Further directions for securing and using individual-tree performance records are given in Farmers' Bulletin No. 794, Citrus-Fruit Improvement: How to Secure and Use Tree-Performance Records.[1]

INDIVIDUAL-TREE ESTIMATE DATA

Individual-tree estimate records are often useful in carrying on tree work where performance records are not available. The tree-estimate data usually include an estimate of the crop borne by the

FIG. 11.—Picking Washington Navel oranges, with field boxes distributed to each tree for the purpose of securing records of the yields of the individual trees. In many cases ladders with three legs are used, so as to avoid injuries to the trees or fruit from the pressure of the ladders. (Highgrove, Calif., April, 1915)

individual tree, with notes on the commercial quality of the fruit and the foliage characteristics. With the aid of suitable note forms and tree numbers these records can be made at the rate of 300 to 500 trees per day by each recorder.

TREE RENEWAL

The term "tree renewal" is here used to mean growing new tops on established trees. In orchards which have been neglected or improperly treated the trees often show evidences of poor physical condition, with low and inferior production. In many such instances tree renewal with improved cultural conditions has resulted in the development of vigorous new tops and greatly improved production. This treatment will not change the type of trees of inferior strains, but will often benefit old or diseased trees or those whose growth has been retarded by unfavorable cultural conditions. Tree renewal is also generally beneficial to trees which have been girdled.

[1] A. D. Shamel. Citrus-fruit improvement: How to secure and use tree-performance records. U. S. Dept. Agr., Farmers' Bul. 794, 16 pp., illus. 1917.

In renewing trees two methods may be used, either gradual renewal through the removal of one or more large branches in succeeding years or complete renewal by cutting off practically all the top growth at one time. When complete renewal is practiced some of the lower horizontal or drooping growth should be left as nurse limbs until new growth has become established. The months of April, May, and June are considered the best season for this work in the Southwest. Large branches and exposed portions of the tree trunks should be protected from sunburn with whitewash.[8]

TOP-WORKING

Top-working is performed for the purpose of improving healthy trees of undesirable strains in established orchards and for changing trees from one variety to another. It is usually best to replant badly diseased or injured trees rather than to top-work them.

FIG. 12.—A tree of the Yellow strain of the Washington Navel orange eight months after the insertion of selected buds from a superior parent tree of the Washington strain. The limb at the right is the nurse limb which was left to assist in the setting and growth of the buds. (Highgrove, Calif., January, 1924)

The season best adapted for top-working varies somewhat with local conditions, but normally the period from March to June, inclusive, is most favorable. Under certain conditions part of the work may be done in the fall, particularly during September and October, the buds lying dormant until the following spring. Spring top-working is usually less costly, as the entire operation of budding and subsequent topping is done within a short period, and if the

[8] Ordinary whitewash may be made by slaking quicklime at the rate of 10 pounds to 2 gallons of water and adding water to bring the wash to the desired consistency. Where protection is wanted for a long period "California tree whitewash" is often used, made by the following formula: Quicklime, 30 pounds; tallow, 4 pounds; salt, 5 pounds. Slake the lime, dissolve the salt in a little water, melt the tallow, and mix it with the salt solution; then add this to the slaked lime. Dilute with enough water to make the mixture flow freely.

stand of buds is unsatisfactory new buds can be inserted with little loss of tree growth.

As a rule from three to five properly spaced framework branches are used in top-working. If one bud is used on each limb it should be inserted on the outer side of the branch about 1 to 2 feet from the tree trunk. It is often desirable, particularly with older trees, to insert buds on the two sides of the limbs to insure a perfect stand, the growth from one being removed if they both live.

The budding operation is the same as in budding seedlings in the nursery, and only carefully selected buds from superior parent trees should be used. If the bark of the framework branches is very thick, as is the case with old trees, it is desirable to thin it or cut out a small section around the inserted buds. After the buds have united properly the budded limbs should be cut off about 6 inches above the buds, the cut surfaces covered with grafting wax or other protective material, and the trunks and exposed portions of the main branches whitewashed. One of the original horizontal or drooping branches of the tree may be left for a year as a nurse limb, but this practice is not essential.

After about six weeks the new growth should be cut back to about half its length, to stimulate branching and to develop a stockier framework. All growth other than that from the selected buds should be removed from time to time; otherwise the new tops may be partly composed of growth from the original trees, thus defeating the object of top-working. Figure 12 shows an orange tree eight months after being top-worked.

About a year after top-working, the ends of the old branches should be again cut back, making a sloping cut with its upper edge flush with the base of the new growth, and the cut surfaces should be protected until they have completely healed. Some propagators prefer when working with old trees to remove the entire head of the tree except a nurse limb, allow sprouts to develop on the stubs, and then bud into a few of these sprouts.

REPLANTING

In nearly all old orchards it becomes necessary from time to time to replace badly diseased or injured trees. Recent experience has shown that young trees can be successfully replanted in such places if proper attention is given them.

The trees to be replaced should be taken out several months in advance of planting the new ones, digging a large hole and spreading the soil in a thin layer to expose it to the sun and air. The new trees can be planted to best advantage in the late spring or early summer, preferably using fresh surface soil mixed with well-rotted manure to refill the holes. The trees should be thoroughly watered as soon as they are planted, and special arrangements should be made to keep the soil moist and in good tilth until they become fully established.

To prevent undue competition with neighboring trees, trenches should be dug at least 2 feet deep and 6 or 8 feet long midway between the young and the adjacent older trees. Manure or other organic matter should be applied in these trenches, which should then be filled with soil.

TRANSPLANTING BEARING TREES

It sometimes becomes necessary to transplant bearing trees to new locations. While trees up to 50 years of age have been successfully moved, it is probable that it can be most economically done with those that are not more than 10 or 15 years old. Only healthy and productive trees are worth transplanting in commercial practice.

The best season for this work is during the early spring, though it can be done successfully up to midsummer, especially if the roots are balled. The tops of the trees should be cut back to about the same extent as for top-working, the larger cuts covered with grafting wax or other suitable material, and the trunks and remaining limbs whitewashed to protect them from sunburn.

Both the bare-root and balled systems of transplanting have been successfully used, but on account of its comparative simplicity and economy the former is usually preferred. With trees up to about

FIG. 13.—Unloading 6-year-old Valencia orange trees for transplanting; also part of a 100-acre planting of these trees. Later observations showed that trees planted with bare roots as late as this made a better start if cut back more severely. (Santa Paula, Calif., July 27, 1922)

10 years of age a trench about 3 feet deep is dug around each tree, leaving a ball of earth about 5 feet in diameter. The soil of this ball is then carefully removed from the roots with a pointed bar and the taproots are cut about 2½ feet below the surface. The roots should be kept moistened and covered with wet sacks to protect them from drying. Figure 13 shows 6-year-old Valencia orange trees being unloaded for transplanting and a portion of a 140-acre orchard of the trees soon after they were planted.

Individual trees in older orchards sometimes show signs of decadence, with light-colored leaves and partial defoliation. This condition has been found in some instances to be associated with weak, diseased roots or abnormal bud unions and can frequently be corrected by inarching sour-orange seedlings into the trunks of the affected trees. Girdled trees and those having other serious bark wounds can also be successfully treated by inarching as well as by bridge grafting.

An improved method for doing this work which has been successfully used for several years has recently come to the attention of the writers and is illustrated in Figure 14. One or more 1 or 2 year old balled seedlings are set in holes near the tree trunk. A narrow vertical strip of bark about 12 to 15 inches long is carefully removed from the trunk of the affected tree above the bud union, and the top

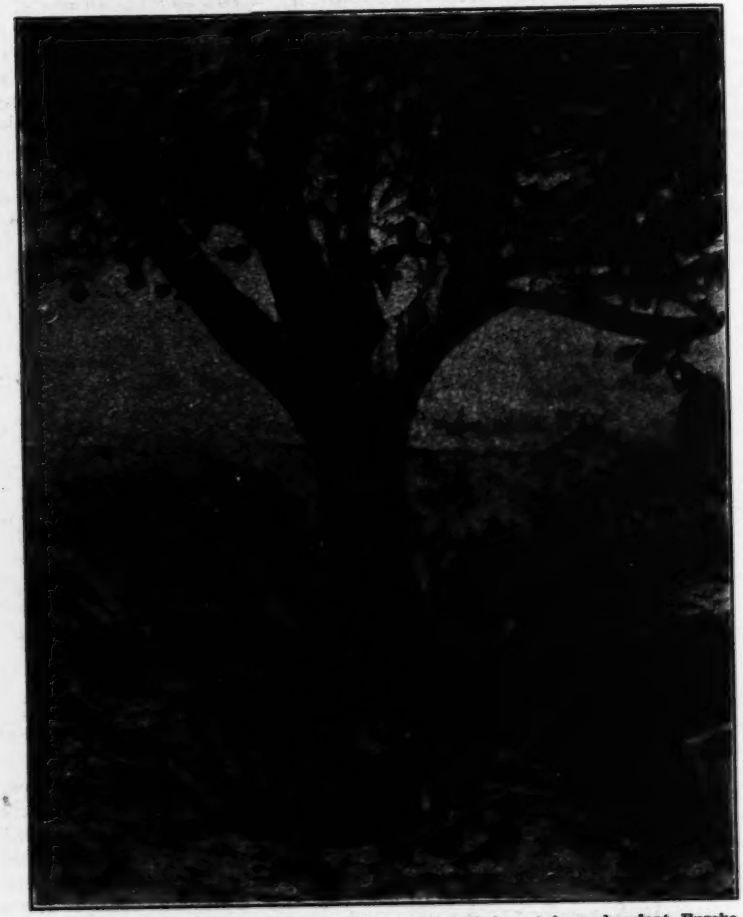

FIG. 14.—Inarching a sour-orange seedling with balled root in a decadent Eureka lemon tree. Note the equipment at the right to keep the grafting wax soft. (Corona, Calif., July, 1921)

of the seedling is cut off at a point slightly higher than the upper end of this wound. The side of the seedling next to the old tree is then shaved off, beginning opposite the lower end of the wound, and the stem of the seedling is nailed in place in the wound with the cut surface of the seedling in contact with the cambium layer of the tree, the upper end of the seedling being placed under a flap of the bark. The wound and the stem of the seedling are then painted with

warm grafting wax, a strip of waxed cloth is placed over the entire wound, and another coating of grafting wax is applied.

This practice provides two long surfaces along which union of the tree and seedling may take place instead of the small area allowed by the method which has been generally used heretofore, insuring a more certain and complete union and the earlier recovery of the tree. This long-contact method can also be used in bridge grafting.

FROST PROTECTION

Practically all present citrus districts are subject to occasional frost damage unless protection is provided, but hillside orchards and those located on slopes or in the path of air currents are usually

FIG. 15.—A lemon tree defoliated by frost, with orange trees behind it only slightly injured. The lemon tree was whitewashed with a power spray outfit as soon as the damage became apparent, in order to protect the trunk and limbs from sunburn. (San Dimas, Calif., April, 1922)

less liable to injury than those on low and level lands. Frost protection is expensive, and the efficient handling of frost-fighting equipment requires careful organization of labor and constant vigilance during cold weather, hence, other things being equal, it is very important to locate citrus orchards where they will be likely to be least injured by low temperatures.

Of the citrus fruits, the orange and grapefruit are about equally susceptible to frost injury, while the lemon is more tender and the lime is most easily injured by frost. It is a common practice to have lemon orchards equipped for frost protection in areas where adjoining orange groves are left unprotected, for the reason that the expense involved in protecting the oranges would not be justified on account of the less frequent danger of loss. Figure 15 shows a

lemon tree entirely defoliated by frost while there was practically no damage to the foliage of the orange trees behind it.

The equipment for frost protection in common use consists of oil heaters, torches for lighting them, and storage tanks for extra supplies of oil. The kind and capacity of the heaters to be used depend upon local conditions, but they should be large enough to hold sufficient oil to burn at least 12 hours, constructed to burn with little or no smoke, and arranged so that the fires can be quickly lighted and extinguished. Iron heaters are liable to rust and depreciate rapidly unless they are protected with asphaltum or other covering. It is usually desirable to clean and dip or paint the heaters after the period of frost danger is over and store them, so they will not be injured. Some growers leave the heaters in the orchard during the summer, placing them in the tree rows or under the trees out of the way of orchard operations.

Torches holding about a gallon and burning a mixture of gasoline and distillate or coal oil are ordinarily used for lighting the heaters, and an ample supply of them should be on hand for emergencies.

Oil tanks should be large enough to hold sufficient reserve for maximum periods of low temperatures. Three times the capacity of the heaters is considered necessary to be safe in possible emergencies, and unless the grower is equipped for an emergency he is liable to find that all his equipment and previous efforts in frost fighting are a dead loss. Oftentimes a number of small growers maintain a storage tank in common. It is desirable to locate the tanks so that oil can be put into and drawn from them by gravity flow. Tank wagons are used in distributing oil to the heaters, and in large orchards the oil is frequently piped to various central points to reduce the haul in filling the heaters.

In order to use frost-protection equipment most efficiently it is necessary to have warning of impending frost. Growers usually make frequent readings of the temperatures in their orchards during times of danger, but in some cases community organizations provide men who obtain systematic readings from reliable thermometers in the coldest areas in their districts and give warning before the danger point is reached. Sometimes automatic frost-alarm equipment is used, which rings a warning bell when the temperature drops to any predetermined point. Normally the time of lowest temperature is just before sunrise.

It is often essential to light the heaters quickly, and enough men should be available to do this work rapidly. When the danger has passed the fires are put out by replacing the covers on the stacks. The heaters should be inspected after every burning and refilled if necessary. If it becomes necessary to refill the heaters while they are in use, it should be done by extinguishing and filling a part of them at a time.

The most efficiently protected orchards are equipped with a heater for every tree, but in some cases fewer may be sufficient. The heaters are usually set on the intersections of the diagonals of the tree rows, as shown in Figure 16, to avoid burning the trees or fruit. In many cases extra heaters are placed in the path of prevailing cold-air currents and along exposed sides of the orchards.

If trees are badly defoliated by low temperatures or other causes, the trunks and limbs should be protected from sunburn by coating

them with whitewash, as shown in Figure 15. Recent experience indicates that pruning frost-injured trees should be deferred for a year or so until the extent of the injuries can be fully determined. Further information on frost protection can be obtained from Farmers' Bulletin No. 1096, Frost and the Prevention of Damage by It.[9]

WINDBREAKS

The practice of growing permanent windbreaks for citrus orchards is now largely confined to localities where heavy winds occur rather frequently. In many districts windbreaks are planted to protect young orchards and are removed when the trees become larger. During recent years many windbreaks have been removed from old orchards because it was found that they were strong competitors with the neighboring orchard trees for moisture and plant food, and in a number of instances they were thought to have increased frost injury to near-by sections by obstructing the normal movement of cold air from the orchards.

FIG. 16.—Burning oil heaters in a California orange orchard for protection from frost, one heater being provided to each tree. (January, 1922)

The trees most commonly used as windbreaks include several species of Eucalyptus, the Monterey cypress, and a recently introduced tree, the athel. Formerly the California pepper tree (*Schinus molle*) was extensively used as a windbreak for citrus plantings, especially along roadways. It is no longer planted for this purpose, and many old plantings have been removed because the tree is one of the preferred hosts of the black scale, and its presence increased the difficulty of controlling the scale in near-by orchards.

[9] United States Department of Agriculture, Weather Bureau. Frost and the Prevention of Damage by It. U. S. Dept. Agr., Farmers' Bul. 1096, 48 pp., illus. 1920.

Of the eucalypts the blue gum (*Eucalyptus globulus*) is the one generally used, because of its rapid growth and its adaptation to climatic conditions in the Southwest. These trees are planted close together and often in double rows. After they reach 25 or 30 feet in height they should be cut back to 16 or 18 feet, so as to induce a strong and dense growth for the protection of the orchard. This tree is unusually free from insect pests or diseases, but is a heavy surface feeder, retarding the growth of near-by orchard trees. The desert gum (*E. rudis*) is sometimes used in preference to the blue gum, as it is thought not to be such a gross surface feeder. The red gum (*E. rostrata*) is a valuable windbreak, especially resistant to drought, which withstands intense heat and is more resistant to frost than the blue gum, but somewhat slower growing. The manna gum (*E. viminalis*) is a hardy species and ranks next to the blue gum in rapidity of growth.

The Monterey cypress (*Cupressus macrocarpa*) makes an extremely desirable windbreak in many sections, because of its low, spreading, dense growth and its resistance to unfavorable climatic conditions. It is usually planted closely in single rows, requires little or no pruning, is free from insect pests and diseases, and is considered less injurious to near-by citrus trees than the eucalypts.

The athel (*Tamarix aphylla*) is exceptionally rapid growing, with dense evergreen foliage, gray green in color, and seems particularly adapted to hot, arid districts, such as the Coachella Valley. It is free from insect pests and diseases so far as known and apparently does not compete as seriously as the eucalypts with adjacent citrus trees except in light sandy soils where the water table is low.

In order to prevent the injurious effects of windbreaks in robbing adjoining orchard trees of soil moisture and plant food, it is desirable to plow deep trenches or to subsoil in the area between the windbreaks and the citrus trees. This trenching or subsoiling should be deep enough to cut the feeding roots of the windbreak trees and frequent enough to prevent their renewed growth from becoming competitive.

CITRUS DISEASES, INSECTS, AND OTHER PESTS

Citrus trees and fruits in the Southwest are subject to serious injuries by a considerable number of diseases and pests, which can be successfully controlled by proper treatments. Information regarding these troubles and methods for their control can be obtained from the Department of Agriculture, Washington, D. C., from the California Citrus Experiment Station, Riverside, Calif., the Arizona Agricultural Experiment Station, Tucson, Ariz., or from local county agents.

HARVESTING AND MARKETING THE CROP

The harvesting and marketing of the citrus crop are specialized operations generally conducted by carefully trained groups rather than by the growers themselves. Extensive investigations by the Department of Agriculture have demonstrated that most of the ordinary decay that is found on citrus fruits in transit and on the markets is the result of improper methods of handling in the various

harvesting and packing operations. Careful handling has thus been shown to be a fundamental requirement in all operations of preparing the fruit for market.

A large part of the fruit shipped from the Southwest is picked by crews hired by the packing houses and carefully trained to do this work properly and economically. Approximately 85 per cent of the crop is marketed through nonprofit cooperative associations of the growers. Except in the case of a few owners of large plantings, the fruit is prepared for shipment in central packing houses, as shown in Figure 17, which are operated by the cooperative associations or by independent jobbers or commission dealers who direct the shipment and sale of the fruit from their houses. A few growers of large acreages pack and ship their own fruit, which is usually marketed by eastern agents.

FIG. 17.—Interior of a lemon packing house, showing workers in the foreground grading fruit from the storage boxes onto shallow trays from which it is packed, as shown in the center. The equipment for orange handling is located at the opposite side of the room. (Corona, Calif., 1922)

Detailed information regarding proper methods of picking, handling, and shipping citrus fruits may be obtained from the U. S. Department of Agriculture, the State experiment stations, or the local county agents.

LABOR CONDITIONS

Labor for the production and handling of the citrus crop may be divided into two classes, ranch and packing house. These classes are not separated by any hard and fast lines, inasmuch as workers are often changed from one kind of work to another, as circumstances make necessary.

Ranch employees include teamsters, autotruck or tractor drivers, irrigators, pickers, pruners, fumigators, and the like. Here, again, the employees often perform different kinds of works at different

periods, but on large ranches they are engaged on one kind of work more or less continuously. On the other hand, on small citrus properties the owner or a few employees may perform all or most of the work, except possibly the picking or fumigating, which is usually done by trained crews.

Packing houses handling lemons are in almost continuous operation throughout the year, but those packing only oranges and grapefruit are closed for a part of the year, in which event the male employees are frequently used for orchard work. Women frequently perform the grading and packing operations.

Ranch employees are generally paid by the day or month, but in certain work they are often hired on a piecework or contract basis. In some kinds of labor requiring particular care or skill wages are often increased by a bonus for more or better work. Teamsters, tractor drivers, irrigators, pickers, pruners, and some other classes of labor are usually paid by the month. Pruners are sometimes paid on a piecework basis, and fumigation and pruning are often contracted with outside labor at a fixed unit rate. Wages vary to some extent with the kind of work, locality, season, or other conditions but are comparatively stable and satisfactory.

Packing-house labor is usually paid on a day basis, except that packers are frequently paid by the box, and the making and lidding of boxes and loading them into cars are sometimes contracted on a unit basis.

During recent years a great deal of attention has been paid to housing accommodations for employees of citrus ranches and packing houses. Houses and gardens are often provided for families, and in many cases recreation rooms, tennis courts, baseball diamonds, or other means of entertainment are supplied. The effect of this development has been to attract and hold a superior class of labor, and it has been found to be an efficient and economical method of maintaining satisfactory labor conditions, especially in small towns or on isolated ranches. The California Fruit Growers Exchange has established a labor bureau to assist growers in securing desirable employees and in improving their living conditions.

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